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A CASE-STUDY VISION

Differential mobile robot for domotic assistance service

Robot móvil diferencial de servicio asistencial domótico

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ABSTRACT

This paper shows a mobile robot whose purpose is to provide comfort and meet various needs that may arise in family homes. This mobile has different sensors that allow monitoring the house remotely, since it has a direct connection between the user and the robot through a graphical interface connected to a wireless network, which shows all the readings of the sensors among other things. The sensory system sends orders to the different actuators that perform the order programmed by the user.

RESUMEN

El presente trabajo muestra un robot móvil cuyo propósito es brindar comodidad, confort y cubrir diversas necesidades que se puedan presentar en los hogares familiares. Esté móvil cuenta con distintos sensores que permiten monitorear la casa remotamente, ya que cuenta con una conexión directa entre el usuario y el robot por medio de una interfaz gráfica conectada a una red inalámbrica, esta interfaz muestra todas las lecturas de los sensores entre otras cosas. El sistema sensorial envía órdenes a los distintos actuadores que cumplen la orden programada por el usuario.

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1. Introduction

The process of control and navigation of autonomous robots is based on the conception that a system is apt to act efficiently in the face of new situations, supported by some specific knowledge. In the words of Miranda Neto [1], an unstructured environment is considered to be one in which there is variation of the illumination factor of the images, the influence of unknown factors, such as mobile and fixed elements. In this environment, the use of vision as the only sensor of data entry of the system for the selection of ideal movements for displacement becomes a difficult task, making the system unstable. In this way, applications must be generated that are composed by a sufficiently ïntelligent"software to manage the mechanical structure during its movement, which have to be equipped with sensors that allow to estimate the distances, location, among other factors.

In this way, mobile robotics has focused on the development of assistant or service robots, looking for the robot-environment interaction to minimize greenhouse gas emissions and, additionally, to achieve energy savings. Currently, it is estimated that residential energy consumption is around 41.2 % of the total energy produced in the country [2]. For this reason, it is necessary to apply efforts in the development of technologies that help to reduce such consumption and to make consumers aware of the environmental impact that this generates. In the last decades, mobile robotics has presented important advances, allowing an integration capacity of home technology called home automation and/or domotics [3, 4]. Therefore, home automation generates an important entity for the economy in homes and helps to reduce the environmental burden, where the service of a mobile robot allows the monitoring of controlled variables, allowing to disconnect devices that for forgetfulness or accidentally are activated [5, 6] or simply issue security alerts remotely with the user.

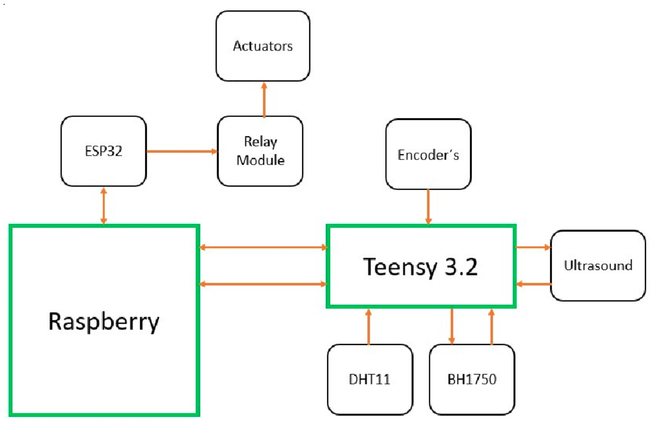
In this way, the work has focused on the development of a differential mobile robot with the performance of domotics devices of low cost systems, which are easily accessible allowing their implementation in most homes, controlling the main variables such as light, temperature and security.

2. Methods

The methodology proposed for the development of the project starts with the kinematic modeling of the differential robot, obtaining the characteristic equations of it, which was validated by means of the Matlab® software. Subsequently, HC-SR04 ultrasound sensors were implemented to detect obstacles and encoders to determine the speed of each of the motors.

As an acquisition system, the Teensy 3.2 embedded plate was used and for processing, the Raspberry PI 3, which manages the information coming from the sensors to send the performance variables to the motors and the wireless system (Figure 1). Once the system was characterized, a graphical interface was created which allowed the user to see the data obtained by the sensors and thus manipulate the actuators at their convenience.

Figure 1: Schematic of the implemented system.



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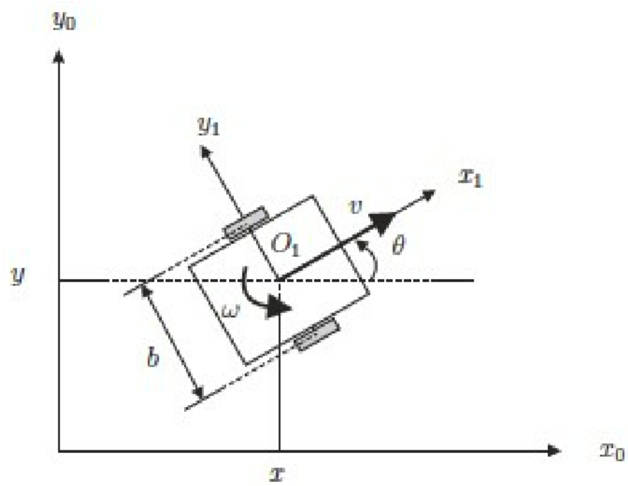
The kinematic model of the mobile differential robot has the characteristic that the robot is non- holonomic, i.e. that it does not have the capacity to move in all its directions, but that it is restricted so that its displacement is only on the y axis, as shown in Figure 2, below. For the first analysis, it must be assumed that the robot is a rigid body, so movement is only possible in the (x_0, y_0) plane. In Campian [7], the position of the robot can be described by a generalized coordinate vector $q = (x, y, \theta)^T$. In the inertial reference system $F_0(x_0, y_0)$, the generalized coordinates define the position and orientation of the robot. The position of the robot is defined by the coordinates (x, y) with respect to its center of mass O_1, point at which the origin of the local reference system $F_1(x_1, y_1)$ is defined, in addition the orientation of the robot is defined by the coordinates θ, which represents the rotation of F_1 in relation to F_0. The movement of the robot can be characterized by the translation speeds v and rotation w over the center of mass of the robot. Two wheels driven independently give to the translation system the movement of the robot. The wheels of the radius r are separated by a distance b.

Figure 2: Schematic of the mobile robot [7].



According to what Campian [8] presented, the movement of the robot is shown in Figure 2, which can be represented by the following kinematic model.

$$\dot{x} = v\cos\theta \tag{1}$$

$$\dot{y} = v\,\text{sen}\,\theta \tag{2}$$

$$\dot{\theta} = w \tag{3}$$

The kinematic model does not take into account the sliding on the wheels. One method to take into account the sliding of the wheels is to consider the ratios of the robot speeds v and w with the wheel speeds, where v_l and v_r are respectively the linear velocity, considering then:

$$v = r\frac{v_l + v_r}{2} \tag{4}$$

$$w = r\frac{v_r - v_l}{b} \tag{5}$$

Where the linear velocities of the left and right wheels are taken in relation to b, which is the distance between the wheels of the robot. The linear velocities of non-slip wheels can be related to their angular velocities as shown in [5], having the following:

$$v_l = rw_l \tag{6}$$

$$v_r = rw_r \tag{7}$$

To obtain the mathematical model of the robot, equations (6) and (7) replaced in equations (4) and (5):

$$v = r\frac{w_l + w_r}{2} \tag{8}$$

$$w = r\frac{w_r - w_l}{b} \tag{9}$$

Expressing equations (1), (2) and (3) in rotation matrices and later replacing in (8) and (9), it obtains:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \text{sen}\,\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \\ w \end{bmatrix} \tag{10}$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \text{sen}\,\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} r\frac{w_l + w_r}{2} \\ \\ r\frac{w_r - w_l}{b} \end{bmatrix} \tag{11}$$

Having the kinematic model, it can be obtained the equations of matrix form, which determine the movement so, it can be said:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} r\frac{\cos\theta}{2} & r\frac{\cos\theta}{2} \\ r\frac{\text{sen}\,\theta}{2} & r\frac{\text{sen}\,\theta}{2} \\ \frac{r}{b} & -\frac{r}{b} \end{bmatrix} \begin{bmatrix} w_r \\ \\ w_l \end{bmatrix} \tag{12}$$

3. Design

In Figure 3, below the prototype of the mobile differential robot has a circular chassis, this in order to make it visually more attractive for a family environment. It contains two engines, each with their respective rims to carry out the movement of the mobile. Only two engines were used for their displacement since the surfaces of the homes are usually flat and this means that the mobile will not require too much power to make its movement. It has an external ultrasound sensor to evade obstacles and internally, it has a humidity, temperature and light sensor, which are the physical variables that the differential mobile will use when traveling in the family home. It has also two encoders, which will make it easier to know the speed of the mobile and indirectly its position and acceleration.

Starting from the prototype design of Figure 3, the corresponding improvements of the different parts and the final assembly of the differential mobile robot were made by means of the Solid Works CAD software as shown in Figure 4.

4. Results and Discussion

The experiments started from the simulation developed in Simulink of Matlab® as shown in Figure 5, where the kinematic model presented by equation (12) was implemented, seeking to validate the movements of the robot with the aim of proposing a control algorithm.

Figure 3: Prototype of differential mobile robot developed.

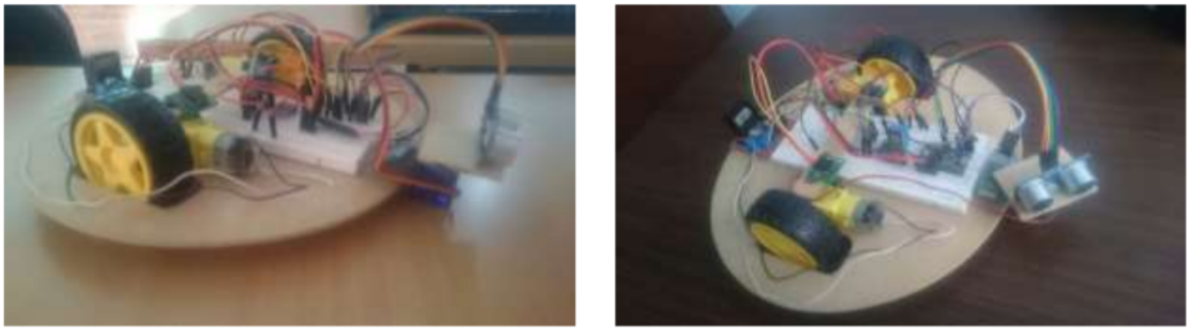


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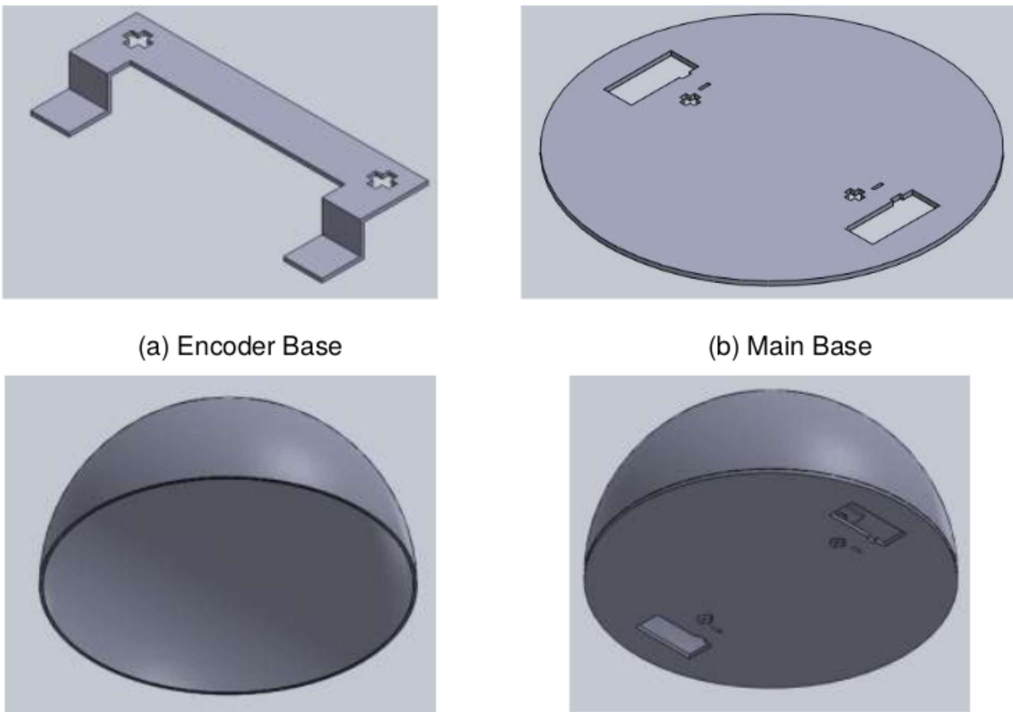
Figure 4: 3D view of the main base and base of the speed encoders.



(a) Encoder Base

(b) Main Base

(c) Robot protection dome

(d) Assembly

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The first validation is made with the movement of the robot in a straight line, where the angular velocities have the same magnitude, generating the robot to move according to the set parameters, as shown in Figure 6(a). Subsequently, a second validation is proposed, which consists of the movement to the right, where the speed of the left wheel is varied in greater magnitude and the magnitude of the left wheel is diminished in turn, resulting in a movement of the robot to the right as shown in Figure 6(b). Finally, the validation of the movement to the left is generated, this being the case contrary to the previous example, obtaining as a result Figure 6(c).

After obtaining the mathematical modeling of the mobile robot, it was continued with the elaboration of a program that, based on modeling, allowed the operation and control of the mobile robot. The logic of this program can be visualized in Figure 7.

Figure 5: Kinematic model implemented in Simulink.

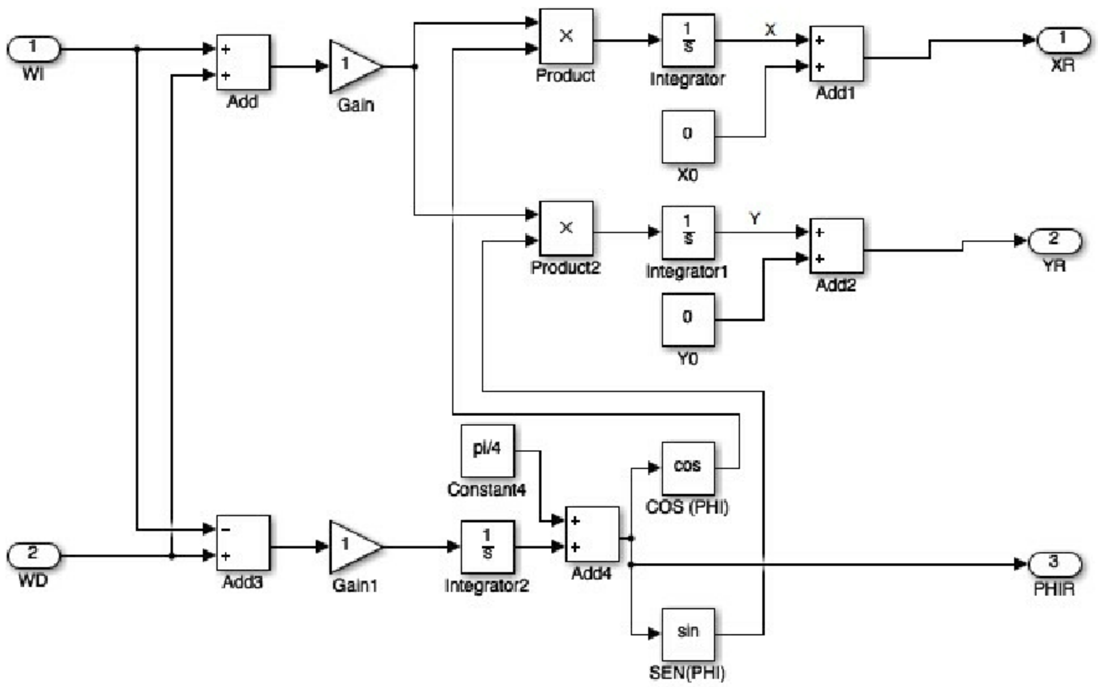

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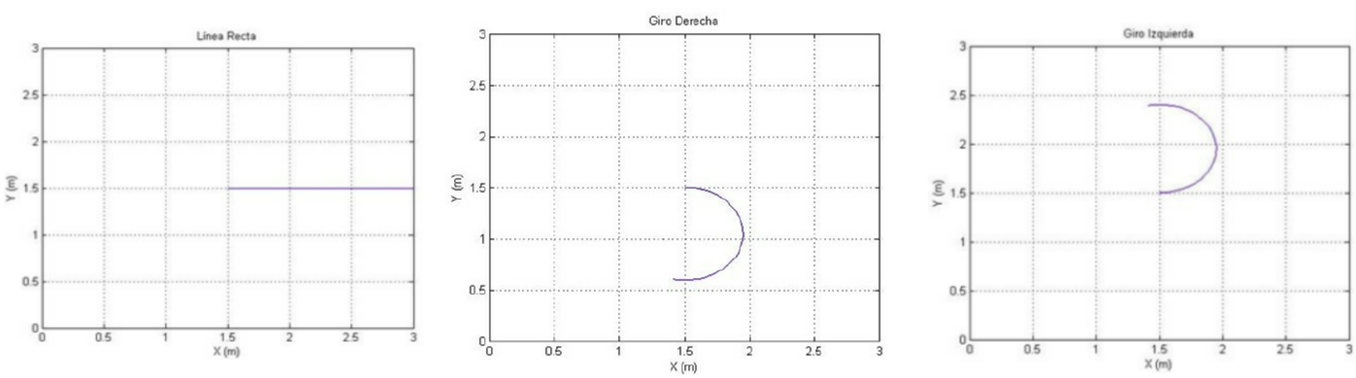
Figure 6: Monitoring of the projected path.



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Taking into account the previous flow diagram, it can be seen that when the mobile robot starts, it begins in an automatic mode until the user tells it to switch to a manual mode, where the mobile robot waits for movement instructions or, alternatively, from the interface, the user tells it to go back to automatic mode.

The graphic interface is presented in Figure 8. This interface sends the control commands via serial port, in which an RS232 drive is connected to Bluetooth in the mobile vehicle. However, the same interface handles home automation peripherals which are wanted to be controlled, as shown in Figure 9.

Figure 7: Flowchart of the autonomous and manual control of the mobile vehicle.

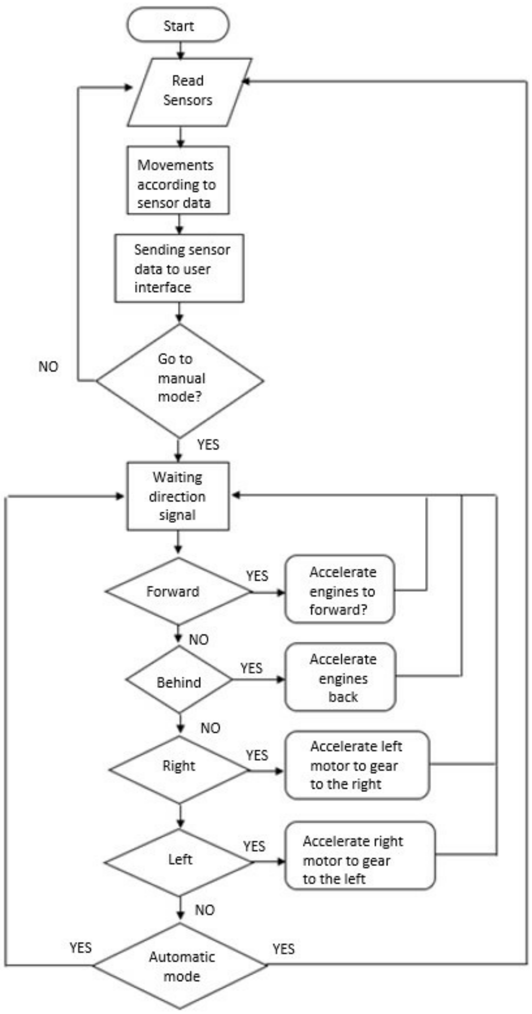

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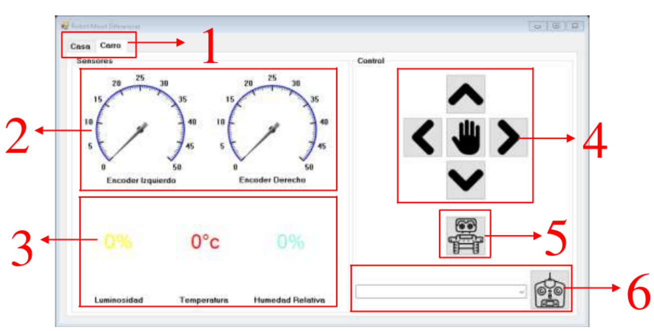
Figure 8: Graphic interface developed in visual studio in the C# programming language.



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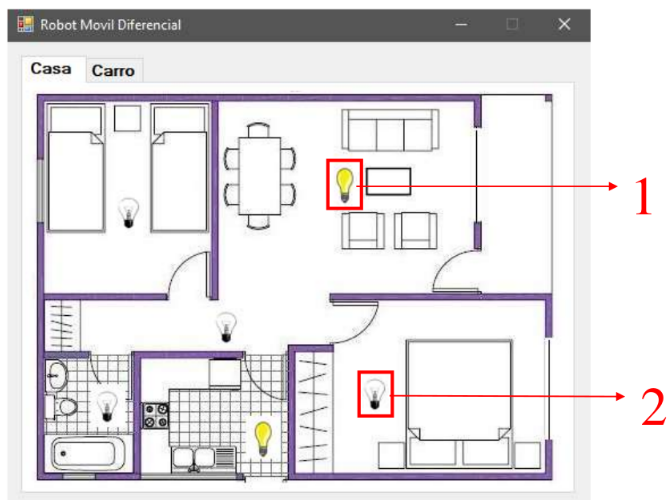
1. House and car tabs, where in the house tab, the actuators installed in the family home are operated, and the car tab is where the mobile robot is controlled, and the states of the sensors are observed.
2. Shows the speed on each wheel of the mobile robot.
3. Shows the percentage of brightness, relative humidity and temperature.
4. Manual control of vehicle displacement from the interface.
5. Automatic movement of the mobile robot.
6. Control of movement of the robot by means of a joystick.

Figure 9: Graphic interface developed in visual studio in the C# programming language.



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1. Representation of a light bulb lit inside the house, clicking on it will change the status of the bulb, from on to off and vice versa.
2. Representation of a light bulb off inside the house, clicking on it will change the status of the bulb.

5. Conclusions

The communication system implemented in the differential robot allows a connectivity of up to 15 meters, within which it can interact with the home automation system, which allows expanding the applications of residential automation developed with the embedded system chosen. With the established operation, it will be possible to generate usage statistics and thus generate an analysis of the energy consumption of the lighting areas implemented.

The response times of the system are short, which is an advantage for future work aimed at developing home automation systems with assistance robot applications. With the obtained databases, artificial intelligence algorithms could be implemented, and this, complemented with a video system, could automate the control of the lights so that the lighting system is pleasant for the user.

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